

REPRODUCTION OF SPANISH MACKEREL, *Scomberomorus maculatus*, FROM THE SOUTHEASTERN UNITED STATES

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ABSTRACT: Spanish mackerel, *Scomberomorus maculatus*, were collected during 1977-80 in the Gulf of Mexico and from North Carolina to south Florida during 1980-81 to describe their reproductive biology. The major spawning period extended from May to September in all areas and peaked during the spring and early summer. Most fish were mature at about 350 mm FL, but size at maturity varied between sexes and sampling areas. Males matured at a smaller size than females. Fecundity was estimated from 52 fish from all areas and ranged from about 100,000 eggs for a 328 mm (295 g) fish to 2,113,000 eggs for a 626 mm (2,415 g) fish. Fork length and total weight were equally good predictors of fecundity.

Spanish mackerel, *Scomberomorus maculatus*, occur along the Atlantic coast of the United States and the Gulf of Mexico (Collette *et al.*, 1978) where they support important commercial and recreational fisheries (Trent and Anthony, 1979). Commercial landings of Spanish mackerel during 1983 were 3,532 t while the recreational catch for 1980 was estimated at 2,579 t from the south Atlantic and Gulf of Mexico (J.E. Powers, National Marine Fisheries Service, Southeast Fisheries Center, Miami, Florida, pers. commun.).

Early biological observations on the Spanish mackerel were made by Ryder (1882) and Earll (1883) in Chesapeake Bay and by Hildebrand and Cable (1938) along the south Atlantic coast. Reports on reproduction and other aspects of their biology were made for waters off Florida (Klima, 1959; Powell, 1975) and off Veracruz, Mexico (Medoza, 1968). A

summary of biological and fisheries data on Spanish mackerel was compiled by Berrien and Finan (1977), and an annotated bibliography was completed by Manooch *et al.*, (1978).

The purpose of this study was to expand our knowledge of Spanish mackerel reproduction by determining spawning season, size-at-maturity, and fecundity from the southeastern United States.

METHODS

Spanish mackerel were collected by port samplers from recreational and commercial catches during 1977-80 from the Gulf of Mexico off Louisiana, Mississippi, and northwest Florida. During 1980-81, specimens were obtained from North Carolina to south Florida. Samples were separated by geographic areas: Mississippi Delta (north central

Gulf of Mexico); northwest Florida (northeast Gulf of Mexico off Panama City, Florida); southeast Florida (Atlantic Ocean off Florida from Ft. Pierce south to the Florida Keys); and Georgia - Carolinas (Atlantic Ocean off Georgia, South Carolina, and North Carolina) (Fig. 1).

Gonads of 2,632 Spanish mackerel (1,469 females and 1,163 males) were collected. Samples from the Mississippi Delta comprised 21.0% of the total, northwest Florida 36.1%, southeast Florida 23.8%, and Georgia - Carolinas 19.1%.

Fish collections were dependent on seasonal availability. Most samples were taken during the spring, summer, and fall, although a few fish from the southeast coast of Florida were collected throughout the year. All fish were sexed and measured to the nearest millimeter (mm) fork length (FL) and to the nearest gram (g) total weight (TW). If

no TW was recorded for a fish, we calculated TW from FL by using the formula $TW = 1.4347 \times 10^{-5} (FL)^{2.9292}$ for Gulf of Mexico fish and $TW = 1.4002 \times 10^{-5} (FL)^{2.9302}$ for Atlantic fish. These length-weight formulae were derived from data taken during this study. Gonads and other viscera were removed, wrapped in cheesecloth, and preserved in 10% formalin. Each gonad was later trimmed of non-gonadal tissue, blotted dry and weighed to the nearest 0.1 g. When large numbers of similar-sized fish were collected, gonads were randomly selected from 10 fish for every 50 mm length interval of each sex.

Three methods were used in determining the maturation stages and reproductive cycle. We first classified the gonads by macroscopic examination using developmental states described by Finucane and Collins (1984). Accordingly, gonads were recorded as Stage IS (infantile), Stage I (immature or resting), Stage

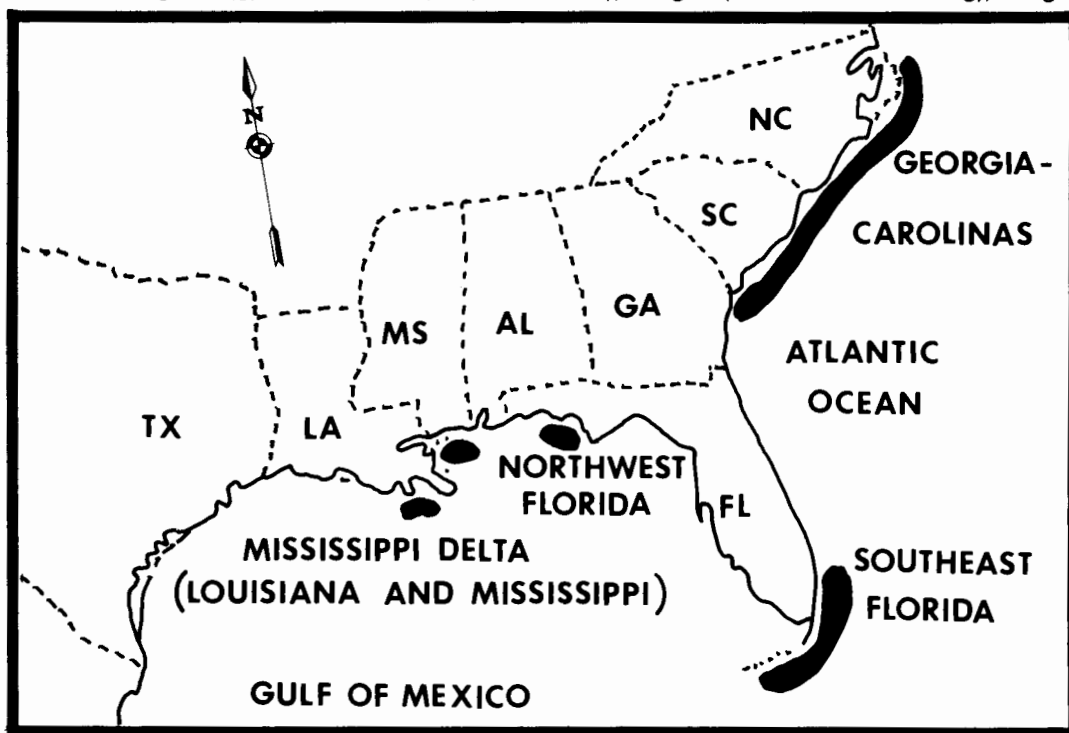


Figure 1. Location of sampling areas in the Gulf of Mexico and Atlantic Ocean for Spanish mackerel collected from 1977-81.

II (early maturing), Stage III (late maturing), Stage IV (ripe), and Stage V (spent). The second method involved the use of a gonadosomatic index (GSI) according to the formula: gonad weight/whole body weight $\times 100$. The GSIs gave a seasonal maturation pattern from which the range, mean, and 95% confidence interval of the mean were computed. These two techniques were the only ones used for males. The third method determined the developmental stages of eggs by microscopic examination. For this method, a wedge-shaped section containing eggs from the outer, middle, and inner zones of the ovary was removed from the mid-point of one randomly selected ovarian lobe. These sections were teased apart to separate the eggs. Measurements and descriptions of eggs and gonad stages were similar to those given for cero by Finucane and Collins (1984). Classification as mature or immature was made on the basis of the presence or absence of vitellogenic eggs greater than 0.2 mm.

Length at maturity was determined by grouping all Stage II-IV fish by 25-mm-FL intervals from April through September for each area and sex. Percentages were then computed for fish with mature gonads for each size interval.

Estimates of fecundity were made from late maturing or ripe (Stages III or IV) fish and were based on counts of all yolked eggs 0.2 mm or greater in diameter according to Hunter and Goldberg (1980) and Morse (1980). We assumed that these eggs would be released some time during the spawning season. The techniques used for our fecundity estimates were described by Finucane and Collins (1984). Fecundity was estimated for each fish using the formula: $F = A/B \times C$, where F = fecundity of fish, A = weight of both ovaries, B = weight of sections, and C = total number of eggs in the sections. Regres-

sions were computed for fecundity based on fork length and weight.

RESULTS

The spawning patterns for Spanish mackerel as determined by monthly mean GSIs were similar for northwest Florida, the Mississippi Delta, and Georgia-Carolina (Figs. 2-4). In these areas, spawning peaked in the spring (May) and gradually diminished during summer and fall. Males and females followed the same general pattern. In contrast, spawning off southeast Florida started earlier in the spring (April) and did not reach a peak until June for females (Fig. 5). Spanish mackerel were not available from the Mississippi Delta, northwest Florida or Georgia-Carolina during the winter months.

Plotting percentages of gonad developmental stages for each area yielded results that agree with the spawning cycles determined from GSIs (Figs. 2-5). Ripe Spanish mackerel first appeared in the spring (April or May) from the areas in the Gulf of Mexico and off Georgia-Carolinas. Gonads were usually in a resting stage between late fall and early spring. Ripe female Spanish mackerel from southeast Florida were detected in the spring and summer and ripe males were present throughout the year except for the fall (Fig. 5).

Size at maturity varied between areas and by sex (Table 1). Females from the Mississippi Delta first matured at 300-324 mm and males first matured at 250-274 mm. In northwest Florida, males matured at 275-299 mm and females at 250-274 mm. Most males larger than 300 mm were mature from the Mississippi Delta, while all males larger than 350 mm were mature from northwest Florida. Males from Georgia-Carolinas were first mature at 275-299 mm, and all males

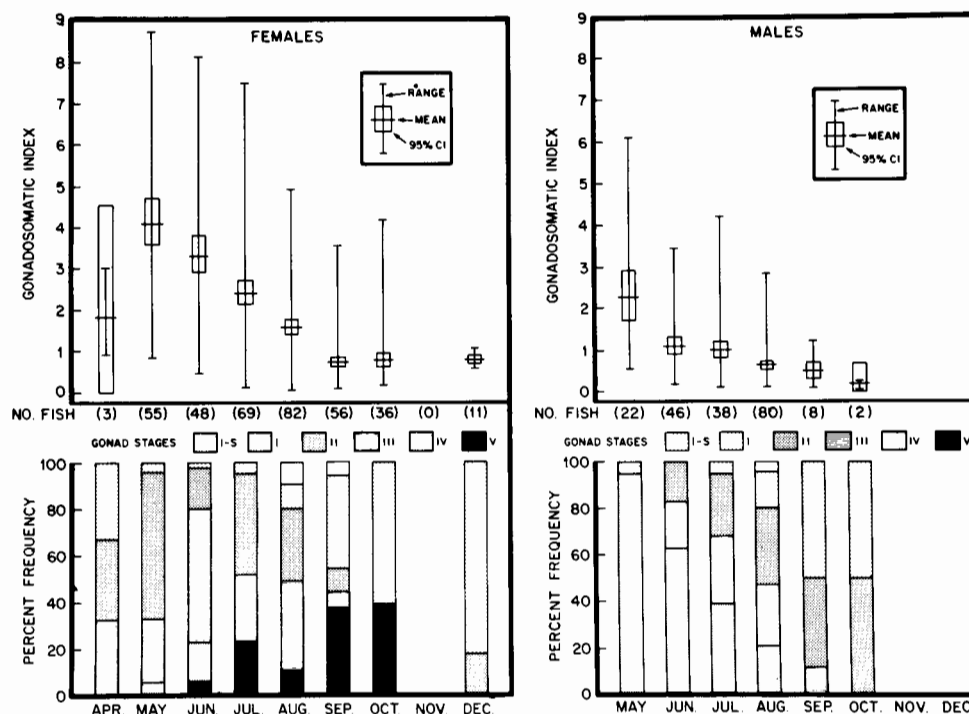


Figure 2. Maturation cycle of female and male Spanish mackerel off Mississippi Delta during 1977-80.

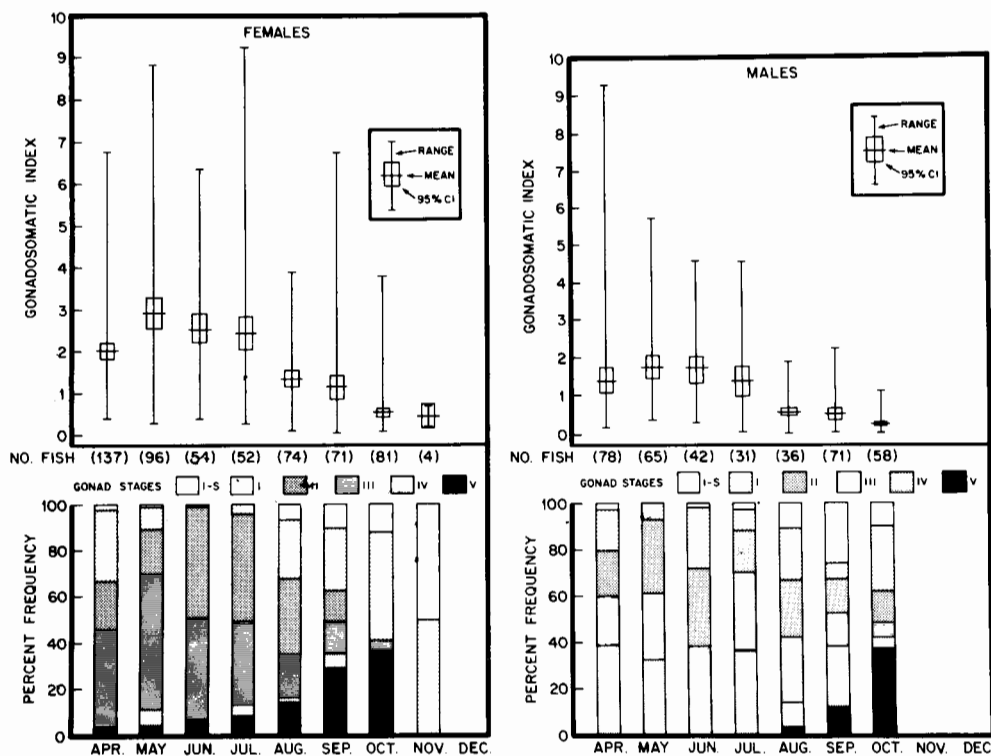


Figure 3. Maturation cycle of female and male Spanish mackerel off northwest Florida during 1977-80.

Table 1. Total number of fish collected from April through September showing percentages of mature (Stage II - V) Spanish mackerel from the Gulf of Mexico and Atlantic coasts.

Fork length (mm)	Mississippi Delta				Northwest Florida				Southwestern Florida				Georgia-Carolinas			
	Females		Males		Females		Males		Females		Males		Females		Males	
	(No.)	(%)	(No.)	(%)	(No.)	(%)	(No.)	(%)	(No.)	(%)	(No.)	(%)	(No.)	(%)	(No.)	(%)
200-224	0	—	1	0.0	0	—	1	0.0	0	—	0	—	0	—	1	0.0
225-249	0	—	1	0.0	1	0.0	0	—	0	—	0	—	0	—	5	0.0
250-274	4	0.0	7	28.6	2	50.0	0	—	0	—	0	—	1	0.0	16	0.0
275-299	8	0.0	50	27.3	4	0.0	39	43.6	0	—	0	—	3	33.3	8	25.0
300-324	9	66.7	9	100.0	12	41.7	44	68.2	0	—	1	0.0	5	40.0	21	28.6
325-349	24	91.7	53	96.2	51	69.8	61	86.8	4	25.0	3	66.6	23	82.6	31	64.5
350-374	36	88.9	37	100.0	45	75.6	38	100.0	12	83.3	30	93.3	43	81.4	74	81.1
375-399	26	96.1	19	100.0	50	88.0	24	100.0	22	100.0	39	100.0	38	94.7	90	88.2
400-424	23	91.3	27	100.0	56	91.1	23	100.0	24	100.0	27	100.0	36	91.7	32	100.0
425-449	21	85.7	19	100.0	28	82.1	5	100.0	20	100.0	13	100.0	13	100.0	11	100.0
450-474	16	93.8	7	100.0	37	91.9	4	100.0	19	100.0	5	100.0	7	100.0	2	100.0
475-499	21	66.7	1	100.0	21	85.7	0	—	9	100.0	7	100.0	5	100.0	5	100.0
500-524	21	100.0	2	100.0	16	100.0	3	100.0	17	100.0	6	100.0	6	100.0	1	100.0
525-549	21	100.0	0	—	6	100.0	1	100.0	9	100.0	5	100.0	3	100.0	3	100.0
550-574	22	100.0	1	100.0	10	100.0	0	0.0	4	100.0	4	100.0	1	100.0	1	100.0
575-599	24	100.0	0	—	2	100.0	0	—	5	100.0	1	100.0	1	100.0	1	100.0
600-624	18	100.0	0	—	0	—	0	—	2	100.0	0	—	2	100.0	1	100.0
625-649	7	100.0	0	—	0	—	0	—	7	100.0	0	—	0	—	0	—
650-674	3	100.0	0	—	0	—	0	—	4	100.0	0	—	1	100.0	1	100.0
675-699	0	—	0	—	0	—	0	—	2	100.0	0	—	0	—	1	100.0
700-724	0	—	0	—	0	—	0	—	1	100.0	0	—	0	—	0	—
TOTAL	304	—	234	—	341	—	243	—	161	—	141	—	188	—	305	—

were mature by 400 mm. Females from the same area were also first mature at 275-299 mm, and all were mature at 425 mm. Most males from southeast Florida were mature at 325-349 mm, and all were mature at 375 mm or larger. Females first matured at 325-349 mm, and all females were mature at 375 mm. All males >350 mm and all females >500 mm were mature from the Gulf of Mexico as compared to >400 mm for males and >425 mm for females from the Atlantic coast.

Fecundity was estimated for 52 females ranging from 312 to 664-mm FL (Table 2). Fecundity generally increased with fish size. The lowest estimate was 100,000 eggs for a 328-mm FL (295 g) female, while the highest was 2,113,000 eggs for a 626-mm FL (2,415 g) female; both fish were from northwest Florida. Females less than 400-mm FL from the Mississippi Delta appeared to produce more eggs than similar-sized females in the other three areas, while females over 500-mm FL from northwest Florida produced more eggs than similar-sized

females in the other three areas.

Regressions fitted by least squares were calculated for each area to show the relationship of fecundity to fork length and total weight. The curvilinear regression $Y = ax^b$ gave the strongest correlation for fish from all areas. Length and weight were both highly correlated to fecundity (Table 3). Regression coefficients showing the relationships of fecundity with length and weight were significantly different ($P = 0.01$) when compared between areas.

DISCUSSION

Spanish mackerel usually spawned from May through September in all our sampling areas and spawning peaked in the spring and summer. A few fish probably spawned in April or October. Gonad maturation data from southeast Florida suggests that some fish may spawn throughout most of the year. Our findings generally agree with those of previous authors. Hildebrand and

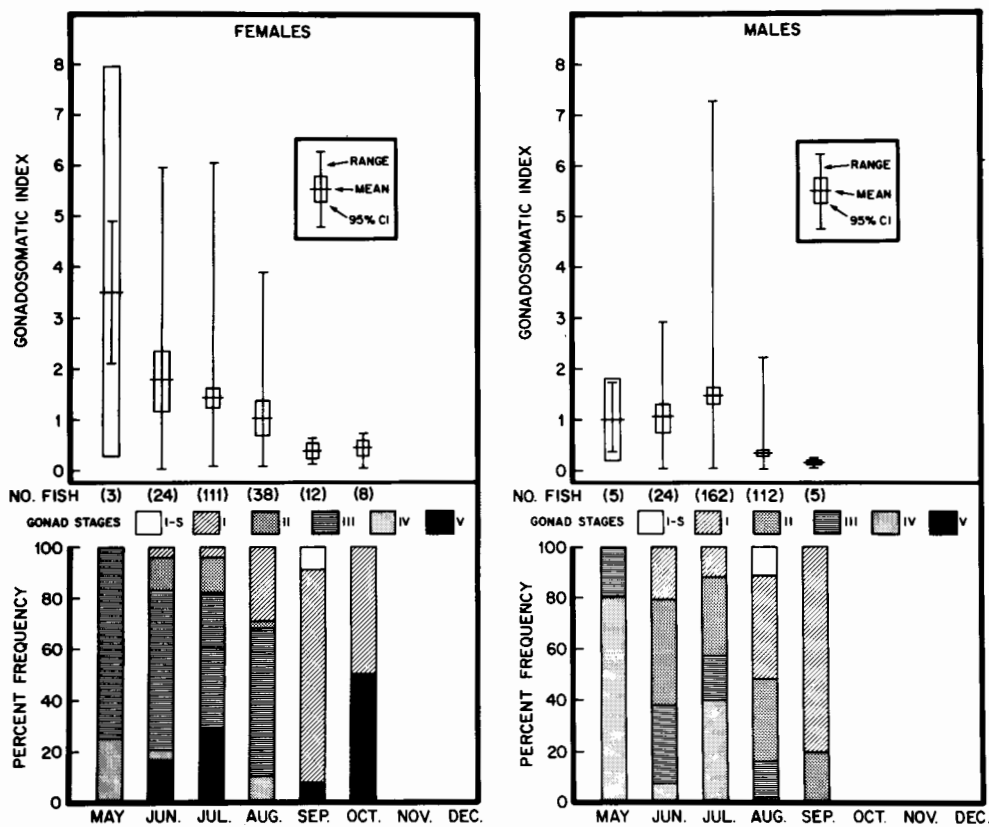


Figure 4. Maturation cycle of female and male Spanish mackerel off Georgia-Carolinas during 1980-81.

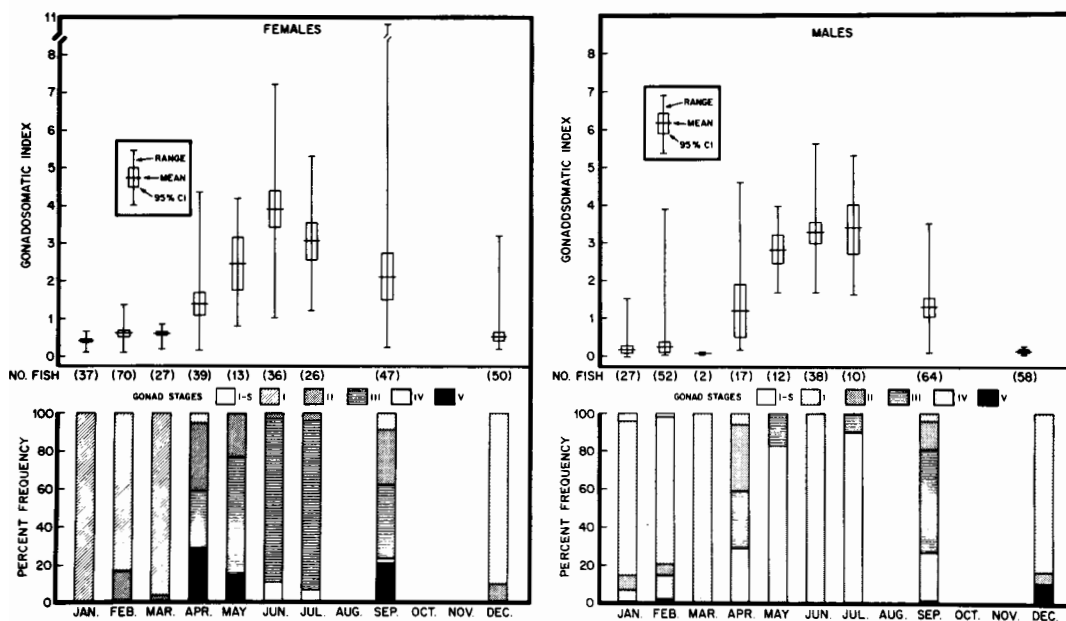


Figure 5. Maturation cycle of female and male Spanish mackerel off southeast Florida during 1980-81.

Table 2. Estimated number of eggs for various sizes and weights of Spanish mackerel from the Gulf of Mexico and Atlantic.

MISSISSIPPI DELTA			NORTHWEST FLORIDA		
FL (mm)	Total weight (g)	Number of eggs	FL (mm)	Total weight (g)	Number of eggs
312	290	283,000	326	272	157,000
347	408	319,000	328	295	100,000
357	332	297,000	338	390	152,000
387	590	590,000	372	460	261,000
402	768	600,000	387	510	292,000
440	738	418,000	412	680	417,000
451	908	450,000	437	911	831,000
511	1,230	653,000	457	915	561,000
534	1,395	980,000	468	926	561,000
567	1,377	1,301,000	491	1,147	1,248,000
583	1,799	827,000	528	1,362	1,074,000
616	2,126	1,272,000	545	1,581	1,062,000
617	2,045	919,000	570	1,748	1,461,000
640	1,477	1,299,000	587	1,907	1,463,000
			626	2,415	2,113,000
			629	2,469	1,615,000

GEORGIA-CAROLINAS			SOUTHEAST FLORIDA		
FL (mm)	Total weight (g)	Number of eggs	FL (mm)	Total weight (g)	Number of eggs
330	336	129,000	354	412	194,000
332	314	153,000	363	315	197,000
376	470	172,000	395	544	274,000
388	539	202,000	426	635	453,000
394	493	215,000	450	726	430,000
400	493	202,000	477	908	430,000
418	671	365,000	486	1,343	596,000
430	672	416,000	573	1,451	606,000
475	976	474,000	580	1,588	692,000
546	1,523	1,161,000	585	1,814	908,000
588	1,648	570,000	664	2,583	1,491,000

Table 3. Relation between fecundity (F) and fork length (FL) and between fecundity and total weight (TW) for Spanish mackerel in four areas.

Parameter	Area	Power function equations	r	r ²	n
Fork length	Mississippi Delta	$F = 1.630 \times 10^{-1} (FL)^{2.093}$	0.915	0.842	14
	Northwest Florida	$F = 7.365 \times 10^{-6} (FL)^{4.098}$	0.970	0.941	16
	Southwest Florida	$F = 1.027 \times 10^{-2} (FL)^{2.863}$	0.962	0.926	11
	Georgia-Carolinas	$F = 1.685 \times 10^{-5} (FL)^{3.915}$	0.968	0.936	11
Total Weight	Mississippi Delta	$F = 3.962 \times 10^{-3} (TW)^{0.744}$	0.903	0.815	14
	Northwest Florida	$F = 8.732 \times 10^{-1} (TW)^{1.296}$	0.976	0.953	16
	Southeast Florida	$F = 9.076 \times 10^{-2} (TW)^{0.919}$	0.970	0.941	11
	Georgia-Carolinas	$F = 6.346 \times 10^{-1} (TW)^{1.314}$	0.976	0.953	11

Cable (1938) noted spawning from late June to late August off North Carolina. H.W. Powles (Gouvernement de Canada, Peches et Oceans, Division des Sciences, halieutiques C.P. 15500, Quebec, Canada, pers. commun.) in the same area captured larvae from May through mid-September. Klima (1959) showed that spawning occurred from July through September off south Florida while Powell (1975) noted spawning from April through September. Wollam (1970) and Dwinell and Futch (1973) collected larvae off the west coast of Florida and Alabama from June through September. McEachran *et al.*, (1980) captured larvae from May through late September to early October with a peak in September off the Texas coast but we found no late fall spawning peak.

We were unable to identify major spawning areas of Spanish mackerel due to the scarcity of ripe fish. Other authors have made references to spawning areas based on the distribution and relative abundance of small larvae less than 3.0 mm SL (Dwinell and Futch, 1973; Houde *et al.*, 1979; McEachran *et al.*, 1980). These studies suggest that the coastal waters off Texas, Alabama, northwest Florida and in the eastern Gulf of Mexico may be important spawning areas for Spanish mackerel. Sampling of spawning stocks and tagging studies are

needed to supply additional data on spawning areas and populations in the Gulf of Mexico and other areas.

Little information is available on the size of Spanish mackerel at maturity. Klima (1959) found in his study of south Florida fish that the smallest mature female was 25 cm FL and the largest immature female was 32 cm FL. His smallest mature male was 28 cm FL and the largest immature male was 34 cm FL. He also indicated that 100% of both sexes were mature at 35 cm FL. Spanish mackerel from Mexican waters were mature at a total length of 35 cm (Medoza, 1968). Our data suggest that most fish were mature at about 350 mm, but size at maturity varied between sampling areas. Males probably mature at a smaller size than females.

The only previous published fecundity data from U.S. waters was reported by Earll (1883) from three fish. He recorded 525,000 eggs from a fish that weighed one pound 13 ounces (883 g) and had a length of 18.5 inches (470 mm). He also estimated that a six pound fish (2.7 kg) had 1,500,000 eggs. These data agree with our estimated fecundities from northwest Florida where a fish of 468 mm FL and 926 g had about 561,000 eggs while a 2,496 g fish had about 1,638,000 eggs. Our egg counts vary for some fish of similar length and weight.

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LITERATURE CITED

- Berrien, P., and D. Finan. 1977. Biological and fisheries data on Spanish mackerel, *Scomberomorus maculatus* (Mitchill). Nat. Mar. Fish. Serv., Sandy Hook Lab. Tech. Ser. Rep. 9:52 p.
- Collette, B.B., J.L. Russo, and L. A. Zavala-Camin. 1978. *Scomberomorus brasiliensis*, a new species of Spanish mackerel from the western Atlantic. Fish. Bull., U.S. 76:273-280.
- Dwinell, S.E., and C.R. Futch. 1973. Spanish and king mackerel larvae and juveniles in the northeastern Gulf of Mexico, June through October 1969. Fla. Dept. Nat. Res. Mar. Res. Lab. Leaflet Ser. 4 pt. 1, No. 24, 14 p.
- Earll, R.E. 1883. The Spanish mackerel, *Cybius maculatum* (Mitch.) Ag.: Its natural history and artificial propagation, with an account of the origin and development of the fishery. Rept. U.S. Comm. Fish Fish. (1880) pt.8:395-426.
- Finucane, J.H., and L.A. Collins. 1984. Reproductive biology of cero. *Scomberomorus regalis*, from the coastal waters of south Florida, Northeast Gulf Sci. 7(1):101-107.
- Hildebrand, S.F., and L.E. Cable. 1938. Further notes on the development and life history of some teleosts at Beaufort, N.C. U.S. Bur. Fish. Bull., 48:505-642.
- Houde, E.D., J.C. Leak, C.E. Dowd, S.A. Berkely, and W.J. Richards. 1979. Ichthyoplankton abundance and diversity in the eastern Gulf of Mexico. Part 1: Executive summary, abstract, text references. Draft Final Report to Bureau of Land Management, 546 p.
- Hunter, J.R., and S.R. Goldberg. 1980. Spawning incidence and batch fecundity in northern anchovy, *Engraulis mordax*. Fish. Bull., U.S. 77:641-652.
- Klima, E.F. 1959. Aspects of the biology and the fishery for Spanish mackerel, *Scomberomorus maculatus* (Mitchill), of southern Florida. Fla. Brd. Conserv. Mar. Res. Lab., Tech. Ser. 27, 39 p.
- Manooch, C.S., III, E.L. Nakamura, and A.B. Hall. 1978. Annotated bibliography of four Atlantic scombrids: *Scomberomorus brasiliensis*, *S. cavalla*, *S. maculatus*, and *S. regalis*. U.S. Dep. Comm., NOAA Tech. Rep. NMFS Circ. 418:166 p.
- McEachran, J.D., J.H. Finucane, and L.S. Hall. 1980. Distribution, seasonality and abundance of king and Spanish mackerel larvae in the northwestern Gulf of Mexico (Pisces: Scombridae). Northeast Gulf Sci. 4(1):1-16.
- Medoza, N.A. 1968. Consideraciones sobre la biología pesquera de la sierra, *Scomberomorus maculatus* (Mitchill), en el Estado de Veracruz. Bios 1:11-22.
- Morse, W.W. 1980. Spawning and fecundity of Atlantic mackerel, *Scomber scombrus*, in the Middle Atlantic Bight. Fish. Bull. U.S. 78:103-108.
- Powell, D. 1975. Age, growth, and reproduction in Florida stocks of Spanish mackerel, *Scomberomorus maculatus*. Fla. Mar. Res. Publ., No. 5, 21 p.
- Ryder, J.A. 1882. Development of the Spanish mackerel (*Cybius maculatum*). Bull. U.S. Fish. Comm. 1(1881):135-172.
- Trent, L., and E.A. Anthony. 1979. Commercial and recreational fisheries for Spanish mackerel, *Scomberomorus maculatus*. In: E.L. Nakamura and H.R. Bullis, Jr. (Eds.) Proceedings: Colloquium on the Spanish and king

mackerel resources of the Gulf of Mexico. Gulf States Mar. Fish. Comm., No. 4, p. 17-32.

Wollam, M.B. 1970. Description and distribution of larvae and early juveniles of king mackerel, *Scomberomorus cavalla* (Cuvier), and Spanish mackerel, *Scomberomorus maculatus* (Mitchill); (Pisces: Scombridae); in the western North Atlantic. Fla. Dept. Nat. Res. Mar. Res. Lab. Tech. Ser. 61, 35 p.